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A PARAMETRIC VARIATION OF DELAYED REINFORCEMENT IN INFANTS

LORI REEVE, KENNETH F. REEVE, AND CLAIRE L. POULSON

QUEENS COLLEGE AND THE GRADUATE CENTER OF THE CITY UNIVERSITY OF NEW YORK

This study is an exploration of the parameters of delayed reinforcement with 6 infants (2 to 6 months old) in two experiments using single-subject repeated-reversal designs. In Experiment 1, unsignaled 3-s delayed reinforcement was used to increase infant vocalization rate when compared to a differential-reinforcement-of-other-than-vocalization condition and a yoked, no-contingency comparison condition. In Experiment 2, unsignaled 5-s delayed reinforcement was used to increase infant vocalization rate when compared to an alternating-treatments comparison condition. The alternating-treatments comparison consisted of 3-min components of differential reinforcement of other behavior and 3-min components of a nontreatment baseline. Successful conditioning was obtained in both experiments. These results contrast with those of previous infancy researchers who did not obtain conditioning with delays of 3 s and who attributed their findings to the limitations of the infant's memory capacity. We present an alternative conceptual framework and methodology for the analysis of delayed reinforcement in infants.

Key words: delayed reinforcement, social reinforcement, vocalizations, infants

The use of delayed reinforcement to produce behavior change has been demonstrated across several species and a variety of responses, including maze learning in rats (Grice, 1948; Wolfe, 1934), bar pressing in rats (Pierce, Hanford, & Zimmerman, 1972), key pecking in pigeons (Dews, 1960; Ferster, 1953; Gleeson & Lattal, 1987; Sizemore & Lattal, 1977; Williams, 1976), and key pressing in monkeys (Ferster & Hammer, 1965). There are inherent problems, however, with the implementation of delayed reinforcement schedules. It may be more difficult to obtain conditioning with delayed, rather than immediate, reinforcement because of the possibility of adventitious reinforcement. Specifically, during the delay interval, nontarget responses may be emitted, and occasionally, these responses may be followed immediately by the delivery of the reinforcer. Most reinforcement schedules are programmed such that the target response will produce the reinforcer with a far greater probability than will the superstitiously conditioned responses. Therefore, many more trials may be required under delayed reinforcement than under immediate reinforcement to increase the rate of target responding differentially. To the extent that these issues are not sufficiently addressed by experimental procedures, researchers may not be able to obtain conditioning with delayed reinforcement.

Delayed reinforcement schedules used with infants have sometimes been unsuccessful in producing conditioning (Millar & Watson, 1979; Ramey & Ourth, 1971). Skill deficits indexed by the age of the infant or the length of the delay may be mitigating factors (Millar, 1972). Indeed, in only one study has conditioning been demonstrated in infants as young as 4 months with delays of reinforcement as long as 3 s (Reeve, Reeve, Brown, Brown, & Poulson, 1992). It would not be surprising to find that additional presentation of the contingency might be important to the acquisition of responding under delayed reinforcement. In the earlier developmental studies, the contingency schedule was presented to each infant only once, and the contingency presentation in these experiments was either 3 min (Millar, 1972; Millar & Watson, 1979) or 6 min (Millar, 1972; Ramey & Ourth, 1971) in length. The length of the contingency segment in studies of delayed reinforcement, or any reinforce-

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ment schedule, may be best determined by the response acquisition patterns of the infant rather than by an a priori time plan.

In addition to the possibility that the experimental phase might be too short to produce conditioning with delayed reinforcement, the baseline phase can also be too short to sample behavior adequately. Short baselines may produce spuriously inflated or deflated response rates because the infant's target and nontarget responding may be influenced by the laboratory surroundings. The earlier developmental studies often used 60-s baselines, in which the experimenter was present only for the final 30 s (Millar & Watson, 1979; Ramey & Ourth, 1971), or 3-min baselines (Millar, 1972). Because these baselines were quite short, response rates may not have stabilized. Thus, the comparison between response rates under delayed reinforcement and an inflated baseline might lead to the inaccurate conclusion that conditioning did not occur. Conversely, the conclusion that conditioning did occur during delayed reinforcement following a deflated baseline might also be spurious.

A procedure that might facilitate conditioning with delayed reinforcement is the explicit signaling of the delay interval immediately following the target response. Although such signals were not used in the early literature on delayed reinforcement with infants (which focused on delays of 1 to 10 s), a review of the literature on studies with nonhumans shows that the use of discriminative stimuli (S^Ds) can result in conditioning with signaled delays of reinforcement extending up to 24 hr. A number of previous studies have shown that the presence of S^Ds facilitates responding under delayed reinforcement with several species, including rats (Azzi, Fix, Keller, & E Silva, 1961; Pierce et al., 1972; Wolfe, 1934), monkeys (Ferster & Hammer, 1965), and pigeons (Richards, 1981).

An additional consideration in experimental design using delayed reinforcement is the delay procedure itself. In contrast to the early developmental literature, conditioning with signaled delays of 3 s in infants has been demonstrated in one recent study (Reeve et al., 1992). This experiment consisted of a repeated-reversal experimental design comparing delayed reinforcement with a differential-reinforcement-of-other-behavior (DRO) schedule. This research design was embedded in an across-subjects multiple baseline design to evaluate the effects of DRO on a nontreatment baseline. The DRO comparison condition was chosen to avoid possible adventitious reinforcement associated with noncontingent schedules and to provide stimulation during baseline as a control for elicitation effects. The dependent variable was the vocalization rate of each of 3 infants, and delivery of reinforcement was signaled immediately following infant vocalization by the illumination of a small red light visible to the infant. Experimental sessions were 12 min long and were conducted over many daily sessions. Condition changes for individual infants occurred when the response rate in the given condition stabilized (in the case of the nontreatment baseline) or when it was apparent that response acquisition had occurred (in the case of DRO and delayed reinforcement). The results demonstrated that response rates during delayed reinforcement were systematically higher than rates obtained during DRO or the nontreatment baseline for all 3 infants.

Although signaled 3-s delayed reinforcement seems to have produced the behavior change demonstrated in the Reeve et al. (1992) study, it is not known whether conditioning would have occurred if the length of the delay had been increased or if the signal had been removed. Thus, there are two major purposes of the present study. The first experiment investigated the use of delayed reinforcement without a signal for the onset of the delay, and the second experiment extended the delay of reinforcement studied with young infants from 3 s to 5 s.

EXPERIMENT 1

Method

Subjects. Three normally developing male infants—Mark, Jason, and Adam—participated as subjects. Their mothers were contacted through fliers posted in local small businesses in the Borough of Queens. At the beginning of the experiment the infants were 119, 108, and 98 days old, respectively. The study was completed within 45 days.

The mental scale of the Bayley Scales of Infant Development (Bayley, 1969) was given to each infant within 1 week of experimentation. Each infant scored within or above the normal range (M = 100); Mark's score was 98, Jason's was 127, and Adam's was 100. Each infant was accompanied by his mother during all experimental sessions.

Setting and apparatus. The study took place in an infant laboratory located in a large university building. The laboratory was fully carpeted and was furnished with a couch and some toys to provide a home-like atmosphere. It also contained a three-panel plywood screen (61 cm by 152 cm) with a window opening (30 cm by 43 cm) in the center panel. An infant car seat was placed behind the screen. The mother sat on the carpet on the other side of the window opening, so the window was at eye level for both mother and infant. The window was covered with a beige venetian blind (76 cm by 43 cm, with 2.5-cm slats). The slats remained closed throughout the experiment. When the blind was down, both mother and infant were unable to see each other. When the blind was raised, the mother could touch and play with the infant through the window opening.

Two 28-V incandescent bulbs with colored crystals were used to signal the mother. A yellow signal light was positioned on the upper left side of the window facing the mother 11 cm from the window opening. A green light was located below the signal light on the mother's side of the screen. Observers illuminated the signal lights, according to the schedule that was in effect, by pressing silent foot switches on the floor.

Two observers sat behind the infant and scored infant vocalizations on portable event recorders (S & K). The observers were seated facing away from each other. Operation of the venetian blind and activation of the signal lights were automatically recorded with solenoid switches that depressed keys on one event recorder.

General procedure. Infants and mothers attended three or four 12-min sessions per week over a period of 4 to 6 weeks. The mother brought the infant to the laboratory, put the infant in the car seat behind the screen, and then sat outside the screen facing the infant through the open window. An experimental session began when the mother lowered the blind, which closed the microswitch on the window.

The independent variable was the schedule of social reinforcement, defined as the raising of the window blind. Social reinforcement occurred whenever two observers turned on the yellow signal light on the mother's side of the screen using foot switches. The light was illuminated only if both foot switches were pressed simultaneously, and it indicated the onset of the delay to the mother. The green light on the mother's side of the screen was timed from the onset of the yellow light and indicated the end of the delay. When the green light was illuminated, the mother raised the blind for 5 s. The mother was asked to make eye contact with the infant and then to play with him while the window blind was raised. An 80-dB buzzer automatically signaled the mother to lower the blind 5 s after its opening. The timing of the blind raising and lowering was measured automatically by a microswitch on the window blind.

During the DRO condition, in which window opening depended on not vocalizing, and during the noncontingent reinforcement condition, the two lights on the mother's side of the screen were illuminated simultaneously. As soon as the lights were turned on, social reinforcement occurred as described above.

The rate of infant vocalization served as the dependent variable. A vocalization was defined as a discrete, voiced sound that occurred within a respiratory unit and was not followed by another voiced sound for a minimum of 1 s. The onset of infant vocalizations was recorded by two independent observers on event recorders during experimental sessions. Interobserver agreement is reported below.

Sessions were terminated if the infant fussed or cried for longer than 1 min. Crying that occurred for less than 1 min was treated procedurally as a vocalization. In the data analysis, however, crying was omitted from the calculation of vocalization rate.

Experimental design and conditions. This experiment was conducted as a single-subject ABACBC reversal experimental design. Three experimental conditions were used in the following order: (a) a schedule of differential reinforcement of behavior other than vocalizations (DRO), (b) a 3-s delayed reinforcement schedule for vocalizations, and (c) noncontingent reinforcement. Condition changes occurred when the graphed data were judged to be stable (Baer, Wolf, & Risley, 1968). The CBC comparison was conducted to focus on the effects of delayed reinforcement. We did not conduct an ACA comparison because of time constraints.

During the DRO condition, as long as the infant did not vocalize the blind was raised every 2 s for a 5-s period of social reinforcement by the mother (as described under the General Procedure). If the infant did vocalize during DRO, the blind opening was delayed until no vocalization occurred for 4 s.

The delayed reinforcement condition was automated (as described above) such that there was an unsignaled 3-s delay between the infant's initial vocalization after the blind was closed and the onset of the green light to signal the mother to open the blind. Infant vocalizations made during the delay interval or during the window-open period did not have any programmed consequences.

In the noncontingent reinforcement condition, the schedule of window-blind opening was determined by yoking each no-contingency session to one of the delay sessions. The delay sessions chosen for yoking for each infant were those three with frequencies of blind openings closest to the median.

The expected differences in response rates were not communicated to the mothers during each condition. Each mother was asked to continue pulling the blind open when signaled and to play with her infant just as she had in the previous condition.

Data analysis. Data on infant vocalization and window-blind opening were analyzed in 3-min intervals. Intervals that were terminated prior to 120 s to meet the infant's needs were discarded. Data on infant crying were analyzed using 5-s interval sampling.

Because the duration of the blind-open reinforcement episodes was not held constant, the measure of the infant's vocalization rate was adjusted in the following manner: The number of vocalizations that occurred when the window was open and the number of seconds that the window was open were subtracted from the data prior to the calculation of the rate of vocalizations during each 3-min interval.

To determine the outcome of the programmed reinforcement procedures in the present study, we calculated the percentage of window-blind openings not preceded by infant vocalization and the percentage of vocalizations followed by window-blind opening within 5 s. This 5-s time frame was selected because on a few occasions the mother took slightly longer to open the blind than the programmed delay of 3 s.

Interobserver agreement. A measure of interobserver agreement for infant vocalization was obtained during 80% of the 169 3-min intervals used in the data analysis. For each part of this experiment, interobserver agreement for the onset of infant vocalizations was calculated on a point-by-point basis by dividing the number of agreements by the sum of the number of agreements and disagreements multiplied by 100%. Vocalizations recorded by both observers within 1 s were counted as agreements. Interobserver agreement during DRO was 83% overall for 49 intervals; during delayed reinforcement, it was 83% overall for 46 intervals; during noncontingent reinforcement, overall interobserver agreement was 82% for 40 intervals.

Interobserver agreement for the occurrence of fussing or crying was calculated by dividing the number of 5-s intervals in which both observers reported fussing or crying by the number of 5-s intervals in which both observers agreed and disagreed about the occurrence of fussing or crying. Interobserver agreement was 85% for 155 intervals containing fussing or crying during DRO, 86% for 73 intervals during delayed reinforcement, and 83% for 121 intervals during noncontingent reinforcement.

Results

Figure 1 presents the number of vocalizations per minute for each 3-min interval during the control and delayed reinforcement conditions for each of 3 infants in Experiment 1. Two types of control conditions are shown: DRO and noncontingent reinforcement. The infants systematically demonstrated an increased rate of vocalization during the unsignaled 3-s delayed reinforcement condition, compared to either type of control condition (DRO or noncontingent reinforcement). Specifically, Mark's vocalization rate increased from 3.5 vocalizations per minute in the first DRO condition to between 9 and 16 vocalizations per minute during the first delayed reinforcement condition. When DRO was reintroduced, Mark's vocalization rate gradually decreased from 8 to about 2.5 vocalizations per minute. Mark's mother chose not to continue the experiment beyond this point.

Jason's vocalization rate followed a pattern

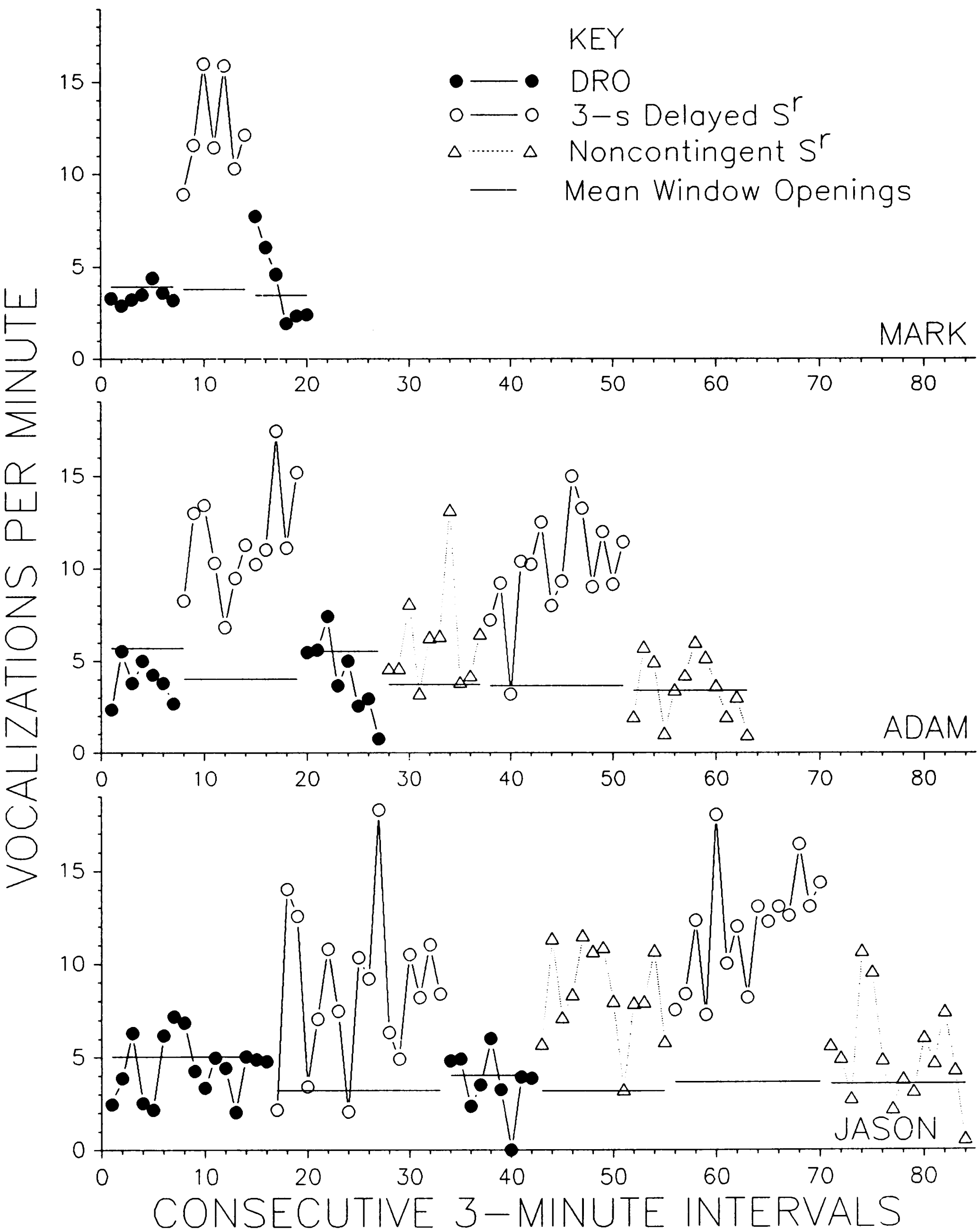

Fig. 1. Rates of vocalization in Experiment 1 for Mark, Jason, and Adam and the mean rate of window-blind opening (horizontal lines) for consecutive 3-min intervals in the DRO condition (closed circles), the unsignaled 3-s delayed reinforcement condition (open circles), and the noncontingent reinforcement condition (open triangles) in a single-subject reversal design.

similar to Mark's, in that his vocalization rate was systematically higher during delayed reinforcement than during the control conditions. The pattern of Adam's vocalization rate was also similar. That is, the vocalization rate was systematically higher during delayed reinforcement than during either the DRO or noncontingent control conditions.

The horizontal lines in Figure 1 illustrate the mean rate of social reinforcement per experimental condition for each infant. The mean rate of window opening was higher during DRO than during the delay condition for all 3 infants for five of six comparisons. The one exception was Mark's final DRO phase, in which the mean rate of window opening was lower than in either of the prior conditions. During DRO, an overall mean of about 4.6 window openings occurred over about 53 intervals (3 min each). During delayed reinforcement, an overall mean of 3.7 window openings occurred for 66 intervals. Although the window-opening rate was programmed to be equal in the noncontingent and delayed reinforcement conditions, mean window opening was slightly lower during the noncontingent condition. An overall mean of 3.5 window openings occurred over 49 components during noncontingent reinforcement. The level of mean openings was similar across all infants and conditions.

An analysis of the presentation of reinforcers is presented in Figure 2. The data reveal that for each infant, the percentage of vocalizations followed by reinforcement within 5 s was systematically lowest during the DRO condition and highest during the delayed reinforcement condition. The percentage of vocalizations followed by reinforcement within 5 s during the noncontingent reinforcement condition for Adam and Jason reached an intermediate level. Conversely, for each infant, the percentage of window openings that were not preceded by vocalizations was systematically highest during the DRO condition and lowest during the delayed reinforcement condition. Intermediate percentages of window openings not preceded by vocalizations occurred during the noncontingent reinforcement conditions for both Adam and Jason.

Not shown in Figure 2 is a further analysis of the delivery of reinforcers during the 3-s delay of the delayed reinforcement condition. Mark, Jason, and Adam produced vocalizations during 35%, 56%, and 60% of the intervals, respectively. There were no systematic differences between the first and second delay conditions for Jason and Adam.

During the DRO condition, fussing or crying occurred in 9% of 2,031 5-s intervals. During the delayed reinforcement condition, fussing or crying occurred in 5% of 2,331 intervals. During the noncontingent reinforcement condition, fussing or crying occurred in 7% of 2,124 intervals. There was no systematic difference between the first and second implementations of a given schedule with respect to this measure.

Discussion

Unsignaled 3-s delayed reinforcement effectively and systematically increased the vocalization rate of the 3 infants compared to both DRO and noncontingent reinforcement control conditions. Elicitation effects, although they may be present, cannot account for the systematic difference in response rate during delayed reinforcement and the control conditions because social stimulation (window opening) rates were, in most cases, systematically higher during DRO than during delayed reinforcement, and because social stimulation rates were nearly equivalent during noncontingent and delayed reinforcement. The analysis of the manner in which the programmed schedules were implemented showed that the delayed reinforcement and DRO schedules functioned as programmed, and that during the noncontingent reinforcement schedule, reinforcers were delivered for both vocalizing and not vocalizing. The level of responding covaried with the proportion of reinforcers delivered following vocalizing and following not vocalizing. These results are consistent with those predicted by Lattal (1974).

In Experiment 2, the length of the unsignaled delay of reinforcement was extended from 3 to 5 s, and an alternating-treatments control condition, containing components of both DRO and window open continuously, was used.

EXPERIMENT 2

Method

Subjects. Three infants—Stacey, Chris, and Arlene—participated in this experiment. Stacey and Arlene were female, and Chris was male. They were 180, 86, and 88 days old, respectively, at the beginning of the study. Each infant was given the mental scale of the Bayley Scales of Infant Development (Bayley, 1969) within 2 days of the first session. Each infant scored within or above the normal range ($M = 100$); Stacey scored 150, Arlene scored 100, and Chris scored 127. As in Experiment 1, only the infants' mothers chose to participate.

Setting and apparatus. The setting and ap-

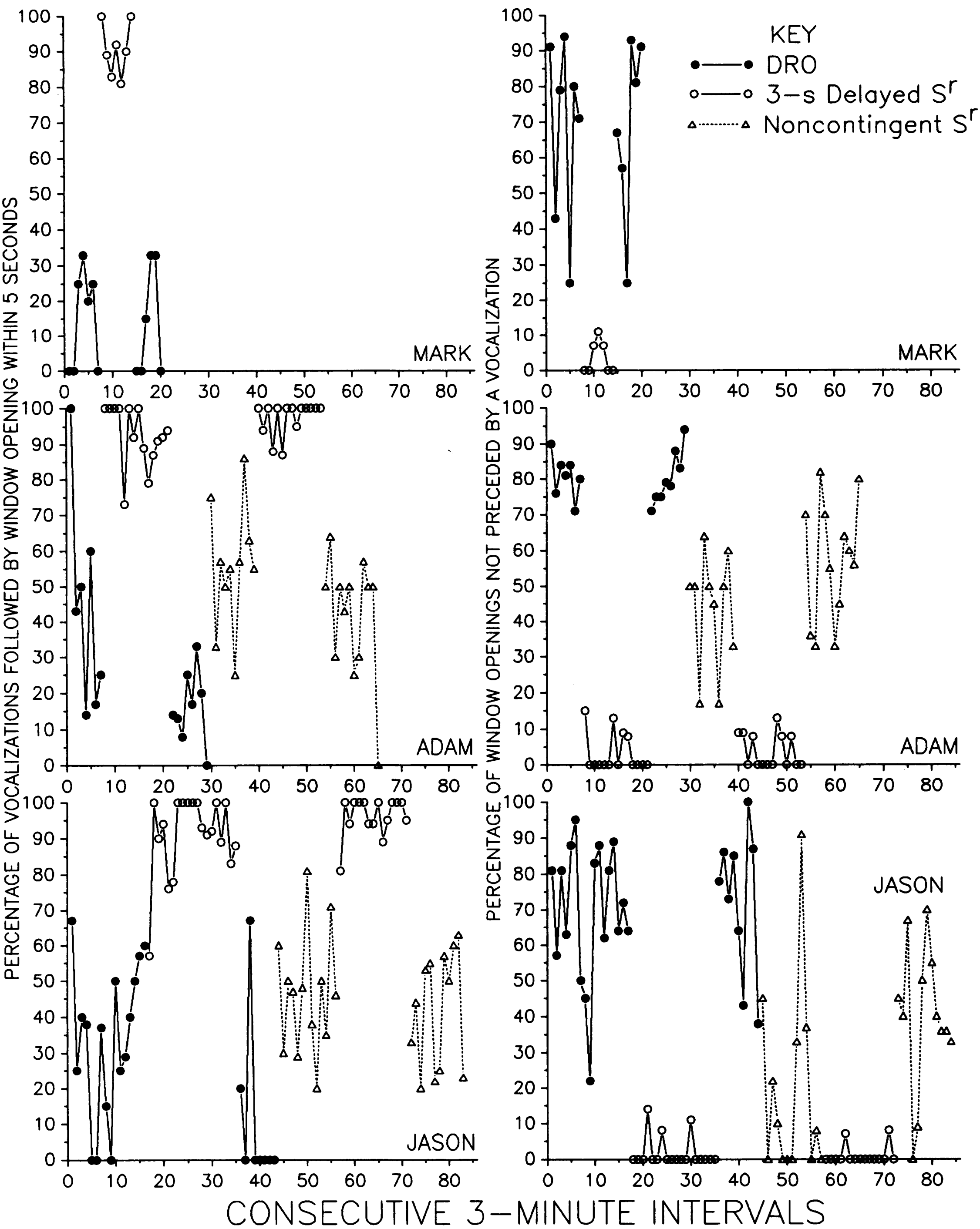

Fig. 2. Analysis of obtained reinforcement patterns in Experiment 1. Percentage of window-blind openings following infant vocalization within 5 s and percentage of window-blind openings not preceded by infant vocalization for Mark, Jason, and Adam for consecutive 3-min intervals in the DRO condition, the noncontingent reinforcement condition, and the unsignaled 3-s delayed reinforcement condition in a single-subject reversal design.

paratus were identical to those in Experiment 1.

Experimental design and procedure. Experiment 2 was conducted in an ABAB single-subject repeated-reversal experimental design comparing 5-s delayed social reinforcement to a control condition. In the control condition, an alternating-treatments design was used to compare a window-open baseline and a DRO schedule in 3-min intervals. We chose a window-open baseline instead of a window-closed baseline because infants tend to cry when seated in front of a closed blind. During the window-open baseline, the blind remained open throughout the 3-min interval. The mother was asked to touch and play with the infant through the opening. Otherwise, the procedures used in Experiment 2 were the same as those used in Experiment 1.

Data analysis. The data were analyzed in the same manner as those in Experiment 1, with one exception: The functional outcome of the programmed reinforcement procedures was measured by calculating the percentage of vocalizations followed by window-blind opening within 7 s, instead of 5 s. A 7-s time frame was selected because the delay interval was 5 s, instead of 3 s as in Experiment 1, and we allowed 2 s for the mother to pull the blind open.

Interobserver agreement. Interobserver agreement for infant vocalizations was obtained as described in Experiment 1 for 88%. of the 123 intervals (3 min each) used in the data analysis. During the window-open baseline, interobserver agreement was 89% for 35 intervals. Interobserver agreement during DRO was also 89% for 35 intervals. Interobserver agreement during delayed reinforcement was 86% for 38 intervals.

Interobserver agreement for fussing or crying was obtained for each 5-s interval as described in Experiment 1. Interobserver agreement was 91% for 87 intervals containing fussing or crying during DRO and 91% for 47 intervals during the window-open baseline. Interobserver agreement was 86% for 83 intervals during delayed reinforcement.

Results

Figure 3 presents the rate of vocalizations for each of 3 infants for each consecutive 3-min interval during the alternating-treatments control condition (alternating 3-min of DRO and the window-open baseline) and delayed reinforcement during Experiment 2. Each infant systematically increased vocalization rate during the unsignaled 5-s delayed reinforcement condition, compared to the DRO condition and the window-open baseline.

For all 3 infants, the DRO and the window-open alternating-treatments condition was associated with similar levels of responding during four of the six alternating-treatments phases. The vocalization rate for all 3 infants was similar during these control conditions, with two exceptions. First, during Stacey's initial alternating-treatments phase, her vocalization rate was highest during the window-open baseline. Second, during the second implementation of the alternating-treatments phase, Arlene's vocalization rate was consistently higher during DRO than during the window-open baseline.

The horizontal lines in Figure 3 represent the mean window openings for each condition. For six of six comparisons, the mean window-opening rate was higher during DRO than during delayed reinforcement. The overall mean window-opening rate during DRO was 5.8 for 37 intervals and was 3.4 for 48 intervals during delayed reinforcement.

An analysis of the presentation of reinforcers is presented in Figure 4. For all infants, consistently higher percentages of vocalizations were followed by window-blind openings within 7 s during the delayed reinforcement condition. In general, during the DRO condition, when vocalizations occurred infrequently, systematically lower percentages of vocalizations were followed by window-blind openings within 7 s than during the delayed reinforcement condition. Conversely, for each of the 3 infants, a systematically higher percentage of window-blind openings were not preceded by vocalizations during the DRO components of the alternating-treatments baseline than during delayed reinforcement.

Not shown in Figure 4 is a further analysis of the delivery of reinforcers during the 5-s delay of the delayed reinforcement condition. Stacey, Chris, and Arlene produced vocalizations during the 5-s delay interval in 52%, 69%, and 62% of the intervals, respectively. There was no systematic difference in vocalization production during the delay interval between the first and second delay conditions.

During the DRO conditions, 6% of 1,368

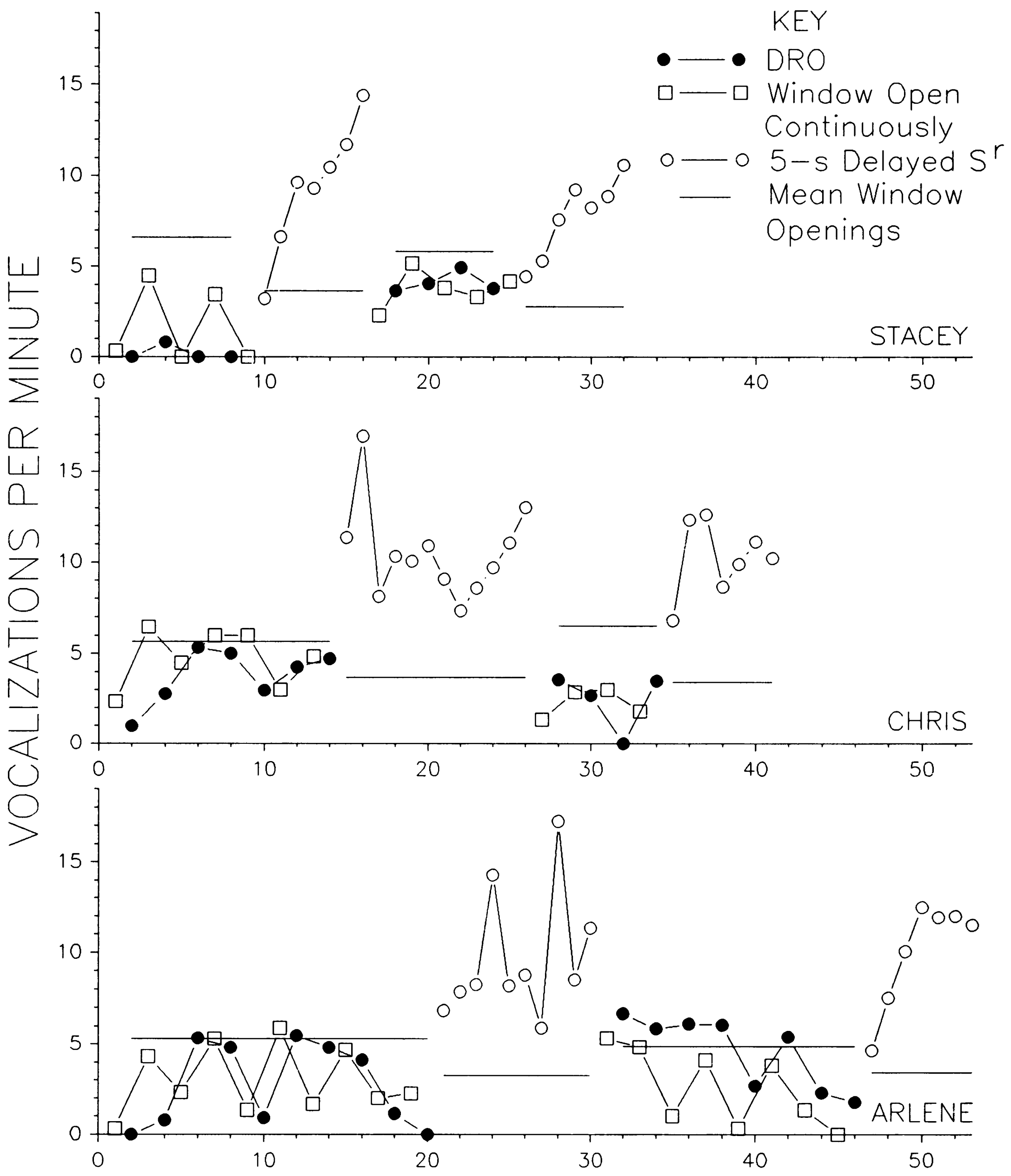

Fig. 3. Rates of vocalizations in Experiment 2 for Stacey, Chris, and Arlene, and the mean rate of window-blind opening for consecutive 3-min intervals during the alternating-treatments baseline and the unsignaled 5-s delayed reinforcement condition in a single-subject reversal design. The alternating-treatments baseline consisted of alternating 3-min components of DRO and a window-open-continuously baseline.

intervals contained fussing or crying. During the window-open baseline, 3% of 1,322 intervals contained fussing or crying, and during the delayed reinforcement conditions, 5% of 1,788 intervals contained fussing or crying. There were no systematic differences between the first and second implementations of a given schedule for this measure.

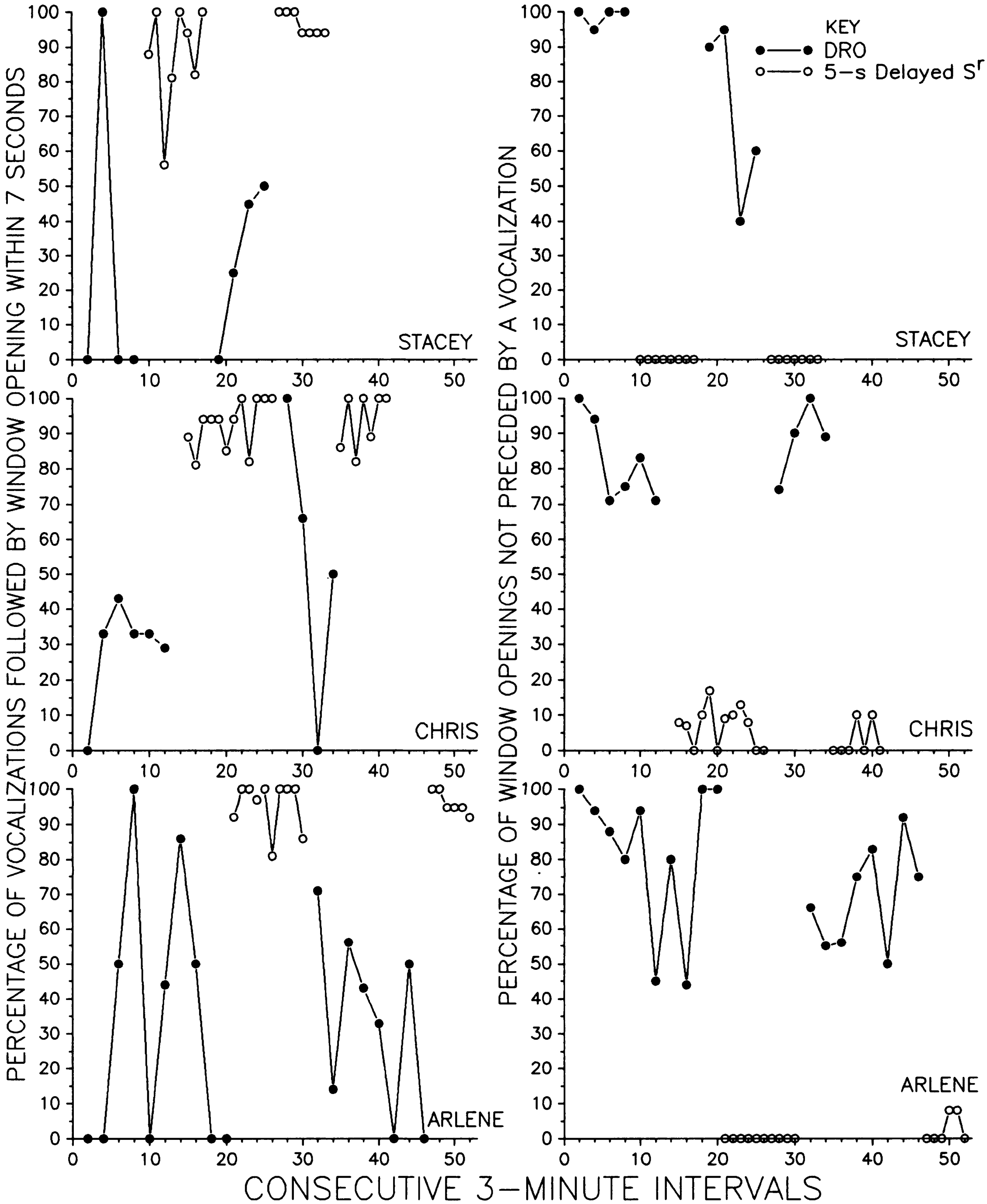

Fig. 4. Analysis of obtained reinforcement patterns in Experiment 2. Percentage of window-blind openings following infant vocalization within 7 s and percentage of window-blind openings not preceded by infant vocalization for Stacey, Chris, and Arlene for consecutive 3-min intervals in the DRO components of the alternating-treatments baseline and the unsignaled 5-s delayed reinforcement condition in a single-subject reversal design.

GENERAL DISCUSSION

In both experiments, delayed reinforcement resulted in a systematic increase in the vocalization rates of infants. These results are consistent with those of Reeve et al. (1992), but not with some of the earlier literature on infants (Millar & Watson, 1979; Ramey & Ourth, 1971). As in the Reeve et al. study, each infant in the current experiments was presented with each experimental condition over many daily 12-min sessions, and conditioning with delayed reinforcement was obtained for delays of 3 s and longer. In contrast, in the earlier studies, the contingency was presented for 3 or 6 min within a single session, and behavioral control was not demonstrated for delays longer than 2 s. The demonstration of delayed reinforcement may require presentation of experimental conditions longer than 6 min repeated across many daily sessions. The length of time and number of sessions required will probably vary with individual infants and the target response chosen. In addition, in the present study, it was found that the use of an S^D to signal the onset of the delay was unnecessary with delays as long as 5 s.

Differences in measurement and procedure between the present study and most of the earlier research may account for the results and contribute to the plausibility of the explanations presented here. These differences include the choice of control condition and the measurement of the presentation of the independent variable relative to target responding. Specifically, in the first experiment of this study, two control conditions, DRO and noncontingent reinforcement, were used. In the second experiment, we used an alternating-treatments comparison condition, consisting of components of DRO and a window-open baseline. Both experiments contained an analysis of the manner in which the reinforcer was presented. Previous studies investigating delayed reinforcement with infants used either a continuously open window (Millar, 1972; Millar & Watson, 1979; Ramey & Ourth, 1971) or immediate reinforcement and noncontingent reinforcement as comparison conditions (Millar, 1972). No information on the functioning of the reinforcer was presented in any of these studies.

The use of the DRO schedule as a comparison condition in the present study may have contributed to the clarity of the results. The advantage of the DRO schedule over the noncontingent schedule is that DRO is less likely to produce adventitious reinforcement of target responding. Thus, the rate of target responding under DRO should be lower than that of noncontingent reinforcement, and the comparison between responding under DRO and delayed reinforcement should produce a stronger contrast than the comparison between noncontingent and delayed reinforcement. In fact, when the actual reinforcement rate for target responding was measured in this study, the rate was systematically higher during noncontingent reinforcement than during DRO. Conversely, the actual reinforcement rate following the absence of the target response was systematically lower during noncontingent reinforcement than during DRO. Consequently, the rate of vocalization during noncontingent reinforcement was also systematically higher than during DRO. Because the rate of reinforcement of the target response was systematically higher during delayed reinforcement than during either DRO or noncontingent reinforcement, and because the rate of reinforcement following the absence of the target response was systematically lower during delayed reinforcement than during either control condition, the difference in vocalization rate between delayed reinforcement and the control conditions can be attributed to the delayed reinforcement procedure.

The use of DRO as a control condition against which to compare delayed reinforcement has produced inconsistent results in studies with nonhumans. Dews (1960) demonstrated an increase in responding during delayed reinforcement, and Pierce et al. (1972) showed no difference between DRO and delayed reinforcement. In studies with infants, DRO was used as a control condition by Reeve et al. (1992), and conditioning was demonstrated with delayed reinforcement. Although a programmed DRO schedule should produce little adventitious reinforcement of the target response, analysis of reinforcement rates may nevertheless clarify the reason for the contradictory data of Pierce et al. (1972) and other researchers using DRO schedules.

Analysis of the relation between presentation of the reinforcer and the occurrence of the target response in the present study helps to explain the pattern of responding under each schedule. This analysis is particularly relevant to the interpretation of the results of the noncontingent reinforcement schedule, because this schedule is not necessarily associated with a given proportion of reinforcers delivered following target responding and following the absence of target responding. Without knowing how the behavior interacts with those schedules, we cannot predict the level of responding that will be obtained under a noncontingent schedule. The one previous study with infants that used noncontingent reinforcement as a control condition consisted of several experiments in which the researcher was able to demonstrate the conditioning of responding with delays of reinforcement of 1 and 2 s, but not 3 s (Millar, 1972). Because Millar did not present an analysis of the presentation of reinforcers during delayed reinforcement and the no-contingency control, it is not clear why the 3-s delay did not produce an increase in responding. Although the majority of studies with nonhumans have demonstrated conditioning (Gleeson & Lattal, 1987; Sizemore & Lattal, 1977), at least one did not demonstrate consistent behavior change when comparing delayed reinforcement to a no-contingency control condition (Williams, 1976). An analysis of the presentation of the independent variable might have explained the seemingly contradictory results.

In both experiments of the current study, the rate of reinforcement (window opening) provided information not only on the contingencies but also on the likelihood of elicitation effects. If the rate of window opening in the control condition had been systematically lower than that of the delayed reinforcement condition, the result could be attributed to elicitation by the window opening rather than to the conditioning of infant vocalizations under a delayed schedule. In fact, the mean rate of reinforcement during DRO was generally higher than during delayed reinforcement in both parts of the present study, and it is therefore more likely that reinforcement rather than elicitation accounted for the increase in vocalization rate. Further, the mean rates of window opening during noncontingent and delayed reinforcement schedules in Experiment 2 were nearly equal, again suggesting that elicitation did not account for the higher response rates during delayed reinforcement conditions when compared with the control conditions used in the present studies. Without the measurement of the rate of reinforcer delivery in all conditions, it would not be possible to determine the likelihood of elicitation effects. Comparison conditions in which there is no stimulation are inappropriate for use with schedules of reinforcement because one is merely comparing stimulation and no stimulation rather than noncontingent and contingent reinforcement or two different contingencies (Poulson & Nunes, 1988). In addition, with the exception of the Reeve et al. (1992) study, previous studies on delayed reinforcement with infants have not reported data on the number of reinforcers delivered in various experimental conditions; therefore, one cannot rule out elicitation effects.

It is also important that the definition of the target response be fully operationalized. In the present study vocalization exclusive of fussing or crying was the target response. It was necessary to measure fussing or crying as well as vocalizations to determine whether fussing or crying occurred differentially across conditions and to distinguish cries from vocalizations. In the present study, crying did not vary systematically by experimental condition. In most previous studies, measures of nontarget responses that may have affected the obtained frequency of target responding were not reported.

In this study, responses that occurred during the delay interval did not reset the timer for the reinforcer. This procedure may have resulted in a higher response rate, because responses were sometimes reinforced with delays shorter than the programmed delay. Because 35% to 69% of the delay intervals did contain vocalizations, it is possible that at least some of the responding produced by delayed reinforcement was adventitiously reinforced on a more immediate basis. Previous studies with nonhumans have demonstrated that the use of reset contingencies results in significantly lower rates of responding than the use of delayed reinforcement alone (Dews, 1960). Because infant vocalizing is generally a low-rate response, we chose not to use a reset contingency within our delayed reinforcement procedure. Nevertheless, to control for the effects of adventitious reinforcement during the delay, future studies might compare reset and nonreset procedures with infant vocalizations.

Although discriminative stimuli were not used in the present experiment to signal the delay period, past research with nonhumans suggests that longer delays may warrant the use of such signals for effective conditioning, at least during initial training (Ferster & Hammer, 1965; Richards, 1981; Schaal & Branch, 1988, 1990). As in the two experiments conducted by Schaal and Branch, an S^D may be used during the entire delay period initially, and then the amount of time signaled during the delay may be gradually faded.

As a minor point, it might be noted that the comparison between the window-open baseline and DRO schedules in an alternating-treatments design yielded no systematic differences in response rate. We believe that this was due to a floor effect, because response rates during window-open were low. Perhaps the rapid alternation produced effects different from those that might be obtained from either schedule alone.

It seems clear that conditioning in infants can occur under a range of delayed contingencies. To facilitate this phenomenon, however, a control condition must be carefully chosen and analyzed, the contingencies must be presented repeatedly over time, and discriminative stimuli (such as signal lights) may be required initially during a delay exceeding 5 s.

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